A Chronological review on application of MARXAN tool for systematic conservation planning in landscape

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Abstract— **This paper reviews the major contributions to the systematic conservation planning in landscape with Marxan software throughout a 11-year period from 2005 up to 2015. After surveying many papers in this field, the volume of the existing works is identified and classified. The paper summarizes all of the reviewed papers in two tables. These tables determine the region of study, year of study, selected information for planning, and main contributions in papers. The socio-economic information along with the biophysical information is considered in the majority of papers for planning, which shows the vital function of this information for decision. It is also demonstrated that more attention is paid to systematic conversation planning using toolboxes based on optimization algorithm such as Marxan in recent years. It concludes with comparative graph demonstrating the frequency of applying Marxan software in systematic conservation planning in landscape. So, it can be used as a guideline for researchers in this field.**

Index Terms— **Chronological, MARXAN, protected area (PA), Systematic conservation planning.**

I. INTRODUCTION

Preserving wildlife habitats and populations is performed by the protection of representative natural areas. It is impractical to expect protection for all places to conservation biodiversity, because it would essentially need the protection of the entire planet. The prioritization of sites and then selection of the most representative areas for protection are the suitable alternative to solving this problem [1, 2]. The determined areas should meet the overall goals of systematic conservation planning such as representativeness and persistence [3]. Currently, most of the protected areas have been chosen by a non-systematic approach. The selection of such areas is powered by economic and political considerations which are not totally based on their ecological value. The economic value of many of these areas is relatively low. The goals and criteria for protection usually differ from the goals of the residents of candidate sites or their periphery for protection [4]. Considering all the criteria and goals as well as selecting the largest, most complete, and most integrated areas for protection are the best approach [5].

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Several systematic approaches are introduced to aid the selection of a network of biologically diverse protected areas [6]. Using artificial intelligence is one of these approaches. Computer algorithms are employed by this approach to calculate objective functions and find the best network of areas to be protected and these areas have a high conservation value [4]. The optimal and heuristic algorithms are main types of site selection algorithm. The complex mathematical processes (linear programming) which are used by optimal algorithms against heuristic algorithms use a simple procedure to obtain optimal solutions [7]. The selection of the protected area is performed by several heuristic algorithms. One of the most common heuristic algorithms for optimization and spatial arrangement of suitable sites is simulated annealing (SA) [8]; this algorithm has a multi-dimensional space which is described in terms of objectives and different options are generated that accommodate multi-dimensional goals. At last, areas that meet the objectives are chosen [5]. This algorithm is used in scientific software named Marxan [9] for determining the priority of protected areas and spatial management of sites. Marxan is the most widely used conservation planning software in the world and is provided for solving complex conservation planning problems in landscapes and seascapes. Marxan provides a flexible approach capable of incorporating large amounts of data and using categories. It is computationally efficient and lends itself well to enabling stakeholder involvement in the site selection process [9].

This paper reviews the works in which Marxan software is used as a tool for systematic conservation planning in landscape.

II. APPLICATION OF MARXAN FOR SYSTEMATIC CONVERSATION PLANNING

There has been limited assessment of the sensitivity of conservation planning outcomes to uncertainty associated with the datasets used for conservation planning. Predicted species distribution data are commonly used for conservation planning because the alternatives (e.g. survey data) are incomplete or biased spatially. The reference [10] assesses the sensitivity of conservation planning outcomes to different uses of predicted species distribution data by Marxan tool. The resulting reserve networks differed, and had different expected species representation.

The reference [11] used empirically derived landscape suitability models for the spotted owl and the fisher to evaluate the overlap in habitat suitability for these two old forest-associated predators in an area of northern California affected by the Northwest Forest Plan (NWFP), a bioregional conservation plan. The area includes designated Wilderness

areas and new reserves (Late-Successional Reserves, LSRs) established under the NWFP. This paper used the site selection algorithm Marxan to identify priority habitat areas for each species, and for both combined, and to compare these areas with reserves. The reference [12] introduces a systematic reserve design analysis in Florida based on a simulated annealing site selection algorithm using Marxan software. The analysis considered conservation needs for a variety of natural resources including species, natural communities, high quality watersheds, wetlands, and sustainable forestry. The reference [13] present a systematic reserve selection for 1654 African mammals and amphibians that uses habitat suitability models as estimates of the area occupied by each species. These are based on the geographic range and habitat preferences for each species. It performed the reserve selection analysis with the software Marxan. In [14] is compared the irreplaceability of sites for protecting ecosystems within the Brigalow Belt Bioregion, Queensland, Australia, using two alternative reserve system design tools, Marxan and C-Plan. It set Marxan to generate multiple reserve systems that met targets with minimal area; the first scenario ignored spatial objectives, while the second selected compact groups of areas. Marxan calculates the irreplaceability of each site as the proportion of solutions in which it occurs for each of these set scenarios. The reference [15] introduced a conservation assessment for Maputaland, part of a biodiversity hotspot in southern Africa that is also the focus of the Lubombo Transfrontier Conservation Area (TFCA) initiative between South Africa, Mozambique and Swaziland. The TFCA seeks to establish new state-, private- and communally-managed conservation areas to boost economic development through nature-based tourism and game ranching. The assessment will guide the TFCA process and used a systematic conservation planning approach by Marxan to design a landscape to conserve 44 landcover types, 53 species and 14 ecological processes.

The reference [16] identified priority areas for avian biodiversity within a 3200-km corridor from Yellowstone National Park in Wyoming, US to the Yukon in Canada. This paper applied the conservation planning tool, Marxan, to summarize 21 avian values. Marxan minimizes the area delineated, while simultaneously incorporating multiple criteria (species richness representation, spatial clustering) and biodiversity targets into a single mappable solution. The reference [17] examined the relative merits of static and dynamic (floating) protected areas for the conservation of American marten *(*Martes americana*)* habitat in a dynamic boreal forest of Québec (Canada). Forest dynamics were modeled using a spatially-explicit landscape disturbance model and protected areas were selected based on the quality and compactness of marten home ranges using Marxan. Geographic Information tools (GI tools) have become an essential component of research in landscape ecology. The reference [18] review the use of GIS (Geographic Information Systems) and GI tools in landscape ecology, with an emphasis on free and open source software (FOSS) projects. Specifically, we introduce the background and terms related to the free and open source software movement such as Marxan, and then compare eight FOSS desktop GIS with proprietary GIS to analyze their utility for landscape ecology research. This paper also provides a summary of related landscape analysis FOSS applications, and extensions. The

reference [19] develops two approaches to identify areas important for the conservation of biodiversity in terms of both wilderness quality and biodiversity representation, using Australia as a case study. The first approach aims to achieve biodiversity representation goals in areas with intact native vegetation. The results of this approach would be extremely expensive to implement as they require a large portion of land. The second approach aims to achieve biodiversity representation goals anywhere across the landscape while placing a strong emphasis on identifying spatially compact intact areas. The analysis is performed by Marxan tool. The reference [20] proposes a conceptual structure for exploring the consequences of input uncertainty and oversimplified approximations to real-world processes for any conservation planning tool or strategy. This paper then present a computational framework based on this structure to quantitatively model species representation and persistence outcomes across a range of uncertainties.

These include factors such as land costs, landscape structure, species composition and distribution, and temporal changes in habitat. This paper demonstrate the utility of the framework using several reserve selection methods including simple rules of thumb and more sophisticated tools such as Marxan and Zonation. The reference [21] propose a protocol for integrating the assessment of freshwater and terrestrial priorities in conservation planning, based on a case study from Mpumalanga Province in South Africa. The approach involves the separate assessment of freshwater priority areas by Marxan, and using the outcome to influence the selection of terrestrial priority areas. This allowed both freshwater and terrestrial biodiversity to be incorporated in conservation planning without compromising their unique requirements. Using systematic conservation planning principles, the reference [22] map the spatial components of biodiversity processes (SCBPs) and use these to design broad-scale conservation corridors for Réunion Island. This paper method is based upon a literature review, expert knowledge, spatially explicit base data, conservation planning software, and spatial modeling by Marxan. We combine a target-driven algorithm with least-cost path analyses to delineate optimal corridors for capturing key biodiversity processes while simultaneously considering biodiversity pattern targets, conservation opportunities, and future threats. The reference [23] presents the freshwater component of the spatial assessment, aimed at identifying focus areas for expanding the national protected area system for the benefit of river biodiversity. Conservation objectives to guide the assessment aimed to improve representation of river biodiversity pattern and processes in both new and existing protected areas.

Data to address these objectives were collated in a Geographic Information System (GIS) and Marxan was used as a means of integrating the multiple objectives in a spatially efficient manner. Representation of biodiversity pattern was based on achieving conservation targets for 222 river types and 47 freshwater fish endemic to South Africa. The reference [24] evaluated how four conservation scenarios complied with the principles of systematic conservation planning and analyzed their representativeness, efficiency, and complementarily using 17 vegetation classes as surrogates for regional biodiversity in brazil. It used MARXAN (systematic conservation planning software) to determine the value of the

habitat types protected by each conservation scenario. Historic land use practices have dramatically altered landscapes across all scales, homogenizing them and restricting opportunities for humans and wildlife. The need for multifunctional landscapes which simultaneously provide food security, livelihood opportunities, maintenance of species and ecological functions, and fulfill cultural, aesthetic recreational needs is now recognized. Numerous theoretical and technical tools have been developed to understand different landscape elements such as Marxan, in particular the emerging research area of ecosystem services. A brief review of these tools in [25] not only shows considerable growth and opportunity, but also serves to highlight a lack of research integration and a lag in implementation. The reference [26] introduce a simple new index, "fraction-of-spare," that satisfies all the axioms. For single-species site prioritization, the fraction-of-spare(s) of a site equals zero if this site has no habitat for the species and one if this site is essential for meeting the target area for the species. In-between those limits it is linearly interpolated, and equals area (s)/(total area – target). In an evaluation involving multi-year scheduling of site acquisitions for conservation of forest types in New South Wales under specified clearing rates, fraction-of-spare outperforms 58 existing prioritization indices.

This paper also compute the optimal schedule of acquisitions for each of three evaluation measures (under the assumed clearing rates) using integer programming, which indicates that there is still potential for improvement in site prioritization for conservation scheduling. The results are compared to results of Marxan tool. The reference [27] used simulation procedures to analyze the effects of using different types of distribution data on the performance of reserve selection algorithms in scenarios using different reserve selection problems, amounts of species distribution known, conservation targets and costs. To compare these scenarios the paper used occurrence data from 25 amphibian and 41 reptile species of the Iberian Peninsula and assumed the available data represented the whole truth. The Marxan tool is used for simulation of scenarios. The paper then sampled fractions of these data and either used them as they were, or converted them to modeled predicted distributions. This enabled to build three other types of species distribution data sets commonly used in conservation planning: "predicted", "transformed predicted" and "mixed".

The results of paper suggest that reserve selection performance is sensitive to the type of species distribution data used and that the most cost-efficient decision depends most on the reserve selection problem and on how much there are of the species. The reference [28] extends a widely-used selection algorithm, Marxan, to incorporate several important considerations related to biodiversity processes and management. First the paper relaxes the scorched earth assumption to allow conservation features in non-reserve zones to contribute explicitly to conservation objectives. To achieve this, the paper generates conservation targets at landscape scales rather than focusing purely on the representation of features within reserves. Second, it develops the notion of spatial dependencies further to incorporate spatial heterogeneity in the value of individual conservation features such as habitat types. Using a case study for the Belize Barrier Reef and by Marxan tool, this paper compare

reserve networks generated using proposed new approach with the results of traditional analyses. The reference [29] considers participatory modeling to integrate biodiversity conservation into land use planning and to facilitate the incorporation of ecological knowledge into public decision making for spatial planning. Réunion Island has experienced rapid urban and agricultural expansion, which threaten its unique biodiversity. This context designed three participatory modeling sequences, involving overall 24 multidisciplinary researchers and stakeholders. The simulation results are derived by Marxan tool. Conservation actions frequently need to be scheduled because both funding and implementation capacity are limited. Two approaches to scheduling are possible. Maximizing gain (MaxGain) which attempts to maximize representation with protected areas, or minimizing loss (MinLoss) which attempts to minimize total loss both inside and outside protected areas. Conservation planners also choose between setting priorities based solely on biodiversity pattern and considering surrogates for biodiversity processes such as connectivity.

The reference [30] address both biodiversity processes and habitat loss in a scheduling framework by comparing four different prioritization strategies defined by MaxGain and MinLoss applied to biodiversity patterns and processes to solve the dynamic area selection problem with variable area cost. The analysis results are derived by Marxan software. The reference [31] partitions land costs into three distinct opportunity costs to smallholder agriculture, soybean agriculture and ranching. This paper demonstrate that opportunity costs to single stakeholder groups can be inaccurate measures of true opportunity costs and can inadvertently shift conservation costs to affect groups of stakeholders disproportionately. Additionally, the paper examine how spatial correlations between costs as well as target size affect the performance of opportunity costs to single stakeholder groups as surrogate measures of true opportunity costs. The analysis results are derived by Marxan software. The reference [32] mapped the distribution of the remaining habitat for the 189 birds in Rio de Janeiro state that are officially endangered and/or endemic to the Atlantic Forest. Using those habitat maps, this paper calculated the amount of habitat currently within protected areas for each species. The paper then prioritized all non-protected parts of the state for their avian conservation value and their potential contribution to a comprehensive protected area system by Marxan tool.

The reference [33] presents a conceptual framework for systematic conservation prioritization that explicitly accounts for the connectivity between the terrestrial, marine, and freshwater realms. This paper propose a classification of this connectivity that encompasses: (1) narrow interfaces, such as riparian strips; (2) broad interfaces, such as estuaries; (3) constrained connections, such as corridors of native vegetation used by amphibians to move between natal ponds and adult habitat; and (4) diffuse connections, such as the movements of animals between breeding and feeding habitats. The determination of priorities are obtained using Marxan tool. The reference [34] describe the efforts of the conservation organization Two Countries, One Forest to identify priority locations in the Northern Appalachian/Acadian ecoregion using MARXAN to classify

locations based on the number of times they are included in a solution. Priority scores range from highly irreplaceable (almost always required) to highly replaceable (almost never required). Conservation goals encompassed ecosystems, threatened and endangered species, geophysical landscape features, and focal carnivores. The reference [35] compare modeled conservation networks derived at regional and local scales from the same area in order to analyze the impact of scale effects on conservation planning. Using the MARXAN reserve selection algorithm and least cost corridor analysis it identified a potential regional conservation network for the Central Valley ecoregion of California, USA, from which it extracted those portions found within five individual counties. The reference [36] derived four abiotic and eight biologically informed classifications of stream reaches to serve as surrogates for biodiversity patterns in the Wet Tropics bioregion, Queensland, Australia. The paper used stream reaches as planning units and, as conservation targets for each surrogate in Marxan tool. In the reference [37], operational planning protocol integrates ecological and socio-economic factors to identify the best spatial options for conserving and restoring biodiversity, inside and outside extant reserves, while minimizing future land-use conflicts. Conservation and restoration targets are formulated for species, habitats and ecological processes that support biodiversity. In this paper the study area of Réunion Island is selected for analyzing. It has experienced rapid urban and agricultural expansion, which threatens its unique biodiversity. Forty three per cent of the island is currently protected in a National Park but only half of this reserve network contributes to the achievement of targets. The Marxan as a tool is used for studying. The reference [38] interviewed land managers in the Eastern Cape Province, South Africa, and mapped their willingness-to-sell their land using a psychometric analytical technique.

The paper examined the, degree to which vegetation type targets are achieved across a planning region,) areal and cost efficiency, and spatial configuration, of candidate protected areas identified as important for achieving conservation targets. It used Marxan software to select near-optimal minimum sets of cadastres which cost-effectively achieve targets and which incorporate spatial design principles. Grassland Program in South Africa is one such initiative and is aimed at safeguarding both biodiversity and ecosystem services. As part of this developing program, the reference [39] identified spatial priority areas for ecosystem services, tested the effect of different target levels of ecosystem services used to identify priority areas, and evaluated whether biodiversity priority areas can be aligned with those for ecosystem services. This paper identified sets of quaternary catchment to achieve targets for ecosystem services while minimizing the total area of quaternary catchments selected. The paper used simulated annealing within Marxan for all analyses. The reference [40] considers the impacts of urbanization in a biodiversity hotspot and as a case study; it evaluates conservation challenges in Metropolitan Cape Town. In this paper a threats layer was compiled using the following 3 sets of data from city spatial planning. The summed threat was determined as the highest threat per planning unit. "High" and "Medium" threat categories were combined and used as a rule in C-Plan and as a cost surface in the Marxan analysis. The reference [41] used the Marxan site-selection program to identify priority shorebird and

waterfowl areas at the ecoregional level. It identified 3.7 million ha of habitat for shorebirds and waterfowl, of which 1.4 million ha would be required to conserve 50% of wintering populations. To achieve a conservation goal of 75%, more than twice as much habitat (3.1 million ha) would be necessary. The reference [42] investigate these issues using a dataset from southern Africa and measure the extent to which changing planning unit shape, size and baseline affects the results of conservation planning assessments by Marxan. it show that using hexagonal planning units instead of squares produces more efficient and less fragmented portfolios and that using larger planning units produces portfolios that are less efficient but more likely to identify the same priority areas. The reference [43] presents a spatially explicit decision method based on Marxan that can be used to identify actions to manage invasive species while minimizing costs and the likelihood of reinvasion. It apply the method to a real-world management scenario, aimed at managing an invasive aquatic macrophyte, olive hymenachne (Hymenachne amplexicaulis), which is one of the most threatening invasives in tropical Australia, affecting water quality, freshwater biodiversity, and fisheries.

The reference [44] evaluate the effect of grain size of species distribution data versus size of planning units on a set of performance measures describing efficiency (ratio of area where species are represented/total area needed), rate of commission errors (species erroneously expected to occur), representativeness (proportion of species achieving the target) and a novel measure of overall conservation uncertainty (integrating commission errors and uncertainty in the actual locations where species occur). The analyzing tool is Marxan. The paper compared priority areas for the conservation of freshwater fish in the Daly River basin (northern Australia). The reference [45] developed a multi-criteria assessment of spatial variability of the vulnerability of three different biodiversity descriptors: sites of high conservation interest by virtue of the presence of rare or remarkable species, extensive areas of high ecological integrity, and landscape diversity in grid cells across an entire region. The paper used simulated annealing within Marxan for all studies. The aim of the freshwater Key Biodiversity Areas (KBAs) methodology presented in the reference [46] is to identify all catchments of global conservation significance. Given that there are limited funds for conservation investment it is necessary to priorities amongst KBAs to produce an efficient reserve network. In the current study the conservation planning software Marxan was utilized to priorities amongst triggered catchments using a simple set of rules (scenarios) to examine the efficiency with which species can be represented and overlap with the existing PA network. To illustrate application of the methodology freshwater KBAs are identified across continental Africa.

The reference [47] uses species distribution modeling to improve conservation and land use planning of Yunnan, China. This paper identify four important aspects of plant species distribution in Yunnan: (1) species diversity hotspots; (2) seven major floristic regions, using a cluster analysis of species presence/absence; (3) priority areas for conservation based on the concept of the 'irreplaceability' value of planning units by Marxan and (4) the percentage remaining natural forest among the species rich and conservation

priority areas, to assess the level of endangerment. Cacti are a plant group of special conservation interest because of their economic value and the threats they face. The refrence [48] studied cactus diversity in the Saltenian Calchaquíes Valleys, the most diverse region in Argentina. Our goals were: to analyze diversity patterns, to evaluate the effectiveness of the extant reserve network, to select the complementary areas for cactus conservation, and to evaluate the effectiveness of endemic cactus diversity as surrogate for all cactus diversity in this region. All of the analyses were performed using Marxan software. Using distribution data of 358 butterfly species, the reference [49] have identified 65 prime butterfly areas in Turkey. Selection of important sites for a single taxon is generally performed using a scoring based system, yet in this study it has adopted Systematic Conservation Planning approach. The selection was based on the principle of complementarily by the site selection software Marxan. The reference [50] assessed the effectiveness of 16 indicator groups in representing these evolutionary and functional components of biodiversity.

It focused our analyses on the entire set of 854 bird species occurring in the Atlantic Forest Biodiversity Hotspot, as a case study. it show that a particular bird order (Apodiformes) is the most effective surrogate group to capture phylogenetic diversity, while the Charadriiformes and restricted-range species are the most effective surrogate group to capture functional diversity. The optimization problems were solved using the simulated annealing algorithm in the software Marxan. The reference [51] demonstrate a novel approach for systematic conservation planning at a fine scale that incorporates dynamic ecological processes (e.g., succession), biodiversity targets and management costs. This paper used the new 'Marxan with Zones' decision support tool to spatially redistribute the major structural types of vegetation within a privately-owned nature park in Israel and facilitate the achievement of multiple conservation targets for minimum cost. In northern Democratic Republic of the Congo (DRC), the African Wildlife Foundation (AWF) has engaged stakeholders and the DRC Government to lead a participatory zoning process in the Maringa–Lopori–Wamba (MLW) Landscape. To assist landscape scale macro-zoning efforts, the reference [52] employed a spatial allocation decision support tool called Marxan to develop a set of three scenarios of potential human and agricultural expansion for 2050. Using the Canadian boreal forest as a case study, the reference [53] demonstrate how biological elements, intact forest landscapes (e.g., dominantly forested areas largely unaffected by recent anthropogenic disturbance); cost (e.g., area and accessibility), and size considerations can be incorporated within spatial conservation planning tools to propose and, following transparent criteria, prioritize potential conservation opportunities within the boreal by Marxan tool. The loss of habitat and biodiversity worldwide has led to considerable resources being spent on conservation interventions. Prioritizing these actions is challenging due to the complexity of the problem and because there can be multiple actors undertaking conservation actions, often with divergent or partially overlapping objectives. the reference [54] explore this issue with a simulation study involving two agents sequentially purchasing land for the conservation of multiple species using three scenarios comprising either divergent or partially overlapping objectives between the

agents by Marxan tool. The use of biodiversity surrogates is inevitable in conservation planning due to the frequent lack of consistent data on biodiversity patterns and processes. Top-down environmental classifications (coarse-filter surrogates) are the most common approach to defining surrogates. Their use relies on the assumption that priority areas identified using surrogates will adequately represent biodiversity. There remains no clear understanding about how the combination of different factors might affect the surrogacy value of these classifications. The reference [79] evaluates the role of three factors that could affect the effectiveness of coarse-filter surrogates: (a) thematic resolution (number of classes), (b) species' prevalence, and (c) the ability of classifications to portray homogeneous communities (classification strength). The reference [55] explores the role of direct and indirect effects of these factors with a simulated dataset of 10,000 planning units and 96 species by Marxan and structural equation modeling (SEM). The reference [56] formulated an approach to explicitly quantify the impact of fire on conservation areas, considering such disturbance as a driver of land-cover changes. The estimated fire impact was integrated as a constraint in the reserve selection process by Marxan to tackle the likely threats or opportunities that fire disturbance might cause to the targeted species depending on their habitat requirements. In this way, it selected conservation areas in a fire-prone Mediterranean region for two bird assemblages: forest and open-habitat species. Many critically endangered species require not only in situ but also ex situ conservation to reduce extinction risk. In the reference [57], all five known wild populations and two artificially managed ex situ populations outside the species' native range of Polemonium kiushianum, a critically endangered herb species in Japan, were studied, using 10 polymorphic microsatellite markers to assess the genetic consequences of habitat degradation on the wild populations and the establishment of ex situ populations. These analyses were conducted using the Marxan software.

The reference [58] proposes a two-stage conservation planning approach. Firstly, the Land-Use Pattern Optimization-library is used to maximize the suitability of habitats for target species by optimizing configuration based on the current landscape. Secondly, the systematic conservation planning tool, Marxan is used to identify protected areas based on the estimated species distributions from the optimal landscape configuration. The reference [59] develops a framework to identify a complementary set of priority areas and enhance the conservation opportunities of Natura 2000 for freshwater biodiversity, using the Iberian Peninsula as a case study by Marxan. it use a systematic planning approach to identify a minimum set of additional areas that would help i) adequately represent all freshwater fish, amphibians and aquatic reptiles at three different target levels, ii) account for key ecological processes derived from riverscape connectivity, and iii) minimize the impact of threats, both within protected areas and propagated from upstream unprotected areas. A systematic approach for prioritization of protected areas is the use of artificial intelligence. This approach employs computer algorithms based on an objective function to identify the best network of areas to be protected. Site selection algorithms are commonly used to identify areas of high conservation value. The reference [60] used three types of heuristic algorithms

(simulated annealing, greedy, rarity) to prioritize areas for protection in Mazandaran Province of Iran using Marxan software. The goal was to select a conservation network with the smallest possible area in which maximum protection targets are achievable. The reference [61] this study has aimed to select a set of priority areas and to determine their priority order by quantifying human disturbances for each area in the Yangtze River Basin (YRB). The habitats of 627 indicator species were predicted as a proxy for biodiversity. The conservation planning tool, Marxan, was used to determine the optimal set of planning units, and three different target scenarios were generated. In addition, under the assumption that if two areas have equal value for conservation, the one suffering more severe disturbance needs more urgent protection than the other, priority ranking analysis was carried out using a BP artificial neural network. The reference [62] demonstrates a new approach to plan cost-effective river rehabilitation at large scales. The framework is based on the use of cost functions (relationship between costs of rehabilitation and the expected ecological benefit) to optimize the spatial allocation of rehabilitation actions needed to achieve given rehabilitation goals (in our case established by the Swiss water act). To demonstrate the approach with a simple example, the paper link costs of the three types of management actions that are most commonly used in Switzerland (culvert removal, widening of one riverside buffer and widening of both riversides) to the improvement in riparian zone quality. It then uses Marxan, a widely applied conservation planning software, to identify priority areas to implement these rehabilitation measures in two neighboring Swiss cantons (Aargau, AG and Zürich, ZH). The reference [63] used the conservation planning software Marxan to select candidate sites for addition to an existing protected area system, based on the following three strategies: (1) focusing on remaining natural habitats; (2) prioritizing agricultural lands for wildlife-friendly farming and agri-environmental measures that can improve conservation value; and (3) a strategy combining the former two. it used area as a surrogate for cost with the aim of minimizing the total area needed to meet its conservation objectives. it focused on breeding bird species in Israel's Mediterranean region, a challenging and relevant case study due to the area's high level of urbanization, population density, and its heterogeneous landscape. Using spatially explicit estimates of bird abundance, the reference [64] evaluated several management alternatives for conserving bird populations in the Prairie Hardwood Transition of the United States. It designed landscapes conserving species at 50% of their current predicted abundance as well as landscapes attempting to achieve species population targets (which often required the doubling of current abundance). It used Marxan with the ArcView Geographical Information System interface, CLUZ to identify parts of the landscape containing core populations of each species for (a) grassland birds, (b) mature forest birds, and (c) early successional forest/shrubland birds. The reference [65] aims to determine the benefit of different terrestrial reserve networks to the condition of coral reefs adjacent to the main islands of Fiji to support the work of Fiji's Protected Area Committee in expanding the national protected area estate through integrated land–sea planning. Options for terrestrial protected area networks were designed using six approaches, where the primary objective of each approach was to either achieve terrestrial conservation goals

(e.g., represent 40% of each vegetation type) or maximize benefits to coral reefs by minimizing potential for land-based runoff. To design terrestrial protected areas, the systematic conservation planning software Marxan was used. Marxan produces spatial options for protected areas that achieve stated conservation targets for a minimum cost. The utility of spatial conservation prioritization (SCP), could be limited by the biases produced by taxonomic uncertainty and by the lack of an accepted taxonomic checklist for a diverse group of species. Using information on the endemic cacti of the Atacama Desert and Mediterranean Chile, The reference [66] assessed the implications for SCP of the existence of two contrasting taxonomies by Marxan. Biological and socioeconomic criteria were combined to design conservation networks for two widely used taxonomic checklists of endemic Chilean cacti.

The reference [67] discusses three potential contributions of social network analysis to systematic conservation planning: identifying stakeholders and their roles in social networks, and characterizing relationships between them; designing and facilitating strategic networking to strengthen linkages between local and regional conservation initiatives; and prioritizing conservation actions by Marxan using measures of social connectivity alongside ecological data. The reference [68] takes the Xinjiang Urgur Autonomous Region (Province), a large area in arid northwest China, as a case to investigate the patterns of woody species diversity and their relationship to environmental factors. At the same time, it aim to evaluate the current protected areas network and improve conservation planning based on woody plant diversity of Xinjiang by Marxan. The paper sampled 133 woody forest species and 220 woody xerophytic species, which are about 10% of the plant species and near 80% of woody species in this region, and modeled current and last glacial maximum (LGM) distributions of these species using the method of species distribution modeling (SDM). Meadows are critical in arid and semi-arid Patagonia because of their importance for regional biodiversity. Despite this, little information on the spatial distribution of meadows is available, which hampers conservation planning. The reference [69] modeled the spatial distribution of meadows across arid and semi-arid Patagonia, Argentina, and investigated conservation status of those areas predicted to contain meadows. This project intends to prioritize and eventually create areas for conservation based on a simulation-based optimization approach, using decision-support software Marxan. Integrated, efficient, and global prioritization approaches are necessary to manage the ongoing loss of species and their associated function. "Evolutionary distinctness" measures a species' contribution to the total evolutionary history of its clade and is expected to capture uniquely divergent genomes and functions. The reference [70] demonstrates how such a metric identifies species and regions of particular value for safeguarding evolutionary diversity. It used simulated annealing as implemented in Marxan and the equal-area grid cell global occurrence matrix of imperiled species to estimate minimum area needs for the prioritization strategies. The reference [71] systematically identified and evaluated priority areas for the protection of large mammals and biodiversity in Liberia under different conservation scenarios. This paper also assessed current proposed protected areas (PPAs) in terms of achieving pre-determined conservation targets, and determined

potential wildlife and biodiversity loss within logging and mining concessions. It systematically collected nationwide data on chimpanzee (Pan troglodytes verus) abundance, large mammal and tree taxonomic diversity, and human threats. It related these to environmental and human impact variables to develop nationwide spatial prediction models that also served as base-layers for spatial prioritization using Marxan. In The reference [72], a new methodology combining the concepts of endemicity and threat in order to provide an objective and highly accurate selection of protected areas is defined. This is a new method to recognize areas of endemism which combines the results yielded by NDM program, based on the optimality criterion, and those obtained using Marxan software, designed to ensure the representation of species in the management of biodiversity.

The method has been tested using the endemic and threatened vascular flora of the South of the Iberian Peninsula (Andalusia). The reference [73] conducted complementarily analysis to achieve the target with regard to species distributions of 172 terrestrial birds in Japan, using in part the results of niche modeling, and identified candidate protected areas not currently included in existing protected areas by Marxan. There was a large difference in landscape structure between existing and candidate protected areas due to the spatial bias of the existing protected areas; these areas were characterized by a high proportion of forest areas and low landscape heterogeneity, while candidate protected areas had a low proportion of forest areas and high landscape heterogeneity. The reference [74] presents the first priority assessment of freshwater ecosystems by Marxan in Mexico at the national scale. Because species' compositional and hydrological conditions vary widely across Mexico we divided the territory into seven distinct regions in order to assign different conservation targets for biodiversity surrogates and to consider specific threats according to their impact in each region. The reference [75] considers land use in priority areas for Borneo's mammals under combined land-cover and climate change projections. Priority areas are selected after accounting for species representation within existing conservation reserves and represent the optimal solution among Marxan and MinPatch analyses that combined 243 species aerial targets for projected suitable habitat in 2010, 2050s, and 2080s. The reference [76] reviews and classifies methods to spatially delineate hotspots. It tests how spatial configuration of hotspots for a set of ecosystem services differs depending on the applied method. It compares the outcomes to a heuristic site prioritisation approach (Marxan).

Tables 1 and 2 show the summery of the reviewed papers. Table 1 describes case study region and type of information for systematic conservation planning and Table 2 illustrates the main contribution in these papers.

Table 1: Case study region and type of information for systematic conservation planning in reviewed papers

Reference	Authors	Year	region	Selected Information for Planning
[10]	K. A. WILSON etal.	2005	-	biophysical
[11]	W. J. ZIELINSKI etal.	2006	Northern California	biophysical
[12]	J. B. OETTING etal.	2006	Florida	socio-economic
[13]	CARLO RONDININI etal.	2006	-	and biophysical / biophysical
[14]	J. CARWARDINE etal.	2007	Queensland, Australia	biophysical
[15]	S. D. Dlamini etal.	2008	Between South Africa, Mozambique and Swaziland	socio-economic and biophysical
[16]	J. L. Pearce etal.	2008	Yellowstone National Park in Wyoming, US and the Yukon in Canada	biophysical
[17]	B. Rayfield etal.	2008	Boreal forest of Québec (Canada)	biophysical
[18]	S. Steiniger etal.	2009	-	-
[19]	C. J. Klein etal.	2009	Australia	biophysical
[20]	W. T. Langford etal.	2009		socio-economic and biophysical
[21]	M. A. Amis etal.	2009	Mpumalanga Province in South Africa	biophysical
[22]	E. Lagabrielle etal.	2009	Réunion Island	biophysical
[23]	J. L. NEL etal.	2009	South Africa	biophysical
[24]	R. LOURIVAL etal.	2009	Brazil	biophysical
[25]	P. J O'Farrell etal.	2010	-	-
[26]	S. J. Phillips etal.	2010	New South Wales	socio-economic and biophysical
[27]	S. B. Carvalho etal.	2010	Iberian Peninsula	biophysical
[28]	H. J. Edwards etal.	2010	Belize Barrier Reef	biophysical
[29]	E. Lagabrielle etal.	2010	Réunion Island	socio-economic and biophysical
[30]	P. Visconti etal.	2010	-	-
[31]	V. M. Adams etal.	2010	-	socio-economic and biophysical
[32]	C. N. Jenkins etal.	2010	Rio de Janeiro	biophysical
[33]	M. Beger etal.	2010		biophysical
[34]	S. C. TROMBULAK	2010	Northern Appalachian/ Acadian	socio-economic and biophysical
[35]	P. R. HUBER etal.	2010	Central Valley of California	biophysical
[36]	S.R. Januchowski-Hartley etal.	2011	Queensland, Australia	biophysical
[37]	E. Lagabrielle etal.	2011	Réunion Island	socio-economic and biophysical
[38]	A. T. Knight etal.	2011	Eastern Cape Province, South Africa	biophysical
[39]	B. N. Egoh etal.	2011	South Africa	biophysical
[40]	A.G. Rebelo etal.	2011	Cape Town	socio-economic and biophysical
[41]	D. STRALBERG etal.	2011	-	biophysical
[42]	B. A. NHANCALE etal.	2011	southern Africa	biophysical
[43]	S. R. JANUCHOWSKI-HARTLEY etal.	2011	tropical Australia	biophysical
[44]	V. Hermoso etal.	2012	Daly River basin (northern Australia)	biophysical
[45]	R. Vimal etal.	2012	-	biophysical
[46]	R.A. Holland etal.	2012	Across continental Africa	biophysical
[47]	M. G. Zhang etal.	2012	Yunnan, China	biophysical
[48]	P. ORTEGA-BAES etal.	2012	Saltenian Calchaquíes Valleys, in Argentina	biophysical
[49]	U. S. ZEYDANLI etal.	2012	Turkey	biophysical
[50]	J. TRINDADE-FILHO etal.	2012	Atlantic Forest	biophysical

[51]	N. Apel etal.	2013	Palestine	socio-economic and biophysical
[52]	J. Nackoney etal.	2013	Northern Democratic Republic of the Congo	socio-economic and biophysical
[53]	P. Powers etal.	2013	Canadian boreal forest	socio-economic and biophysical
[54]	A. Gordon etal.	2013	-	-
[55]	V. Hermoso etal.	2013	-	biophysical
[56]	S. VALLECILLO etal.	2013	Fire-prone Mediterranean	biophysical
[57]	M. Yokogawa etal.	2014	Japan	biophysical
[58]	Y. P. Lin etal.	2014		
[59]	V. Hermoso etal.	2014	Iberian Peninsula	biophysical
[60]	A. Mehri etal.	2014	Mazandaran Province of Iran	biophysical
[61]	L. Zhang etal.	2014	Yangtze River Basin	biophysical
[62]	S. D. Langhans etal.	2014	Switzerland	socio-economic and biophysical
[63]	D. Troupin etal.	2014	Palestine's Mediterranean region	socio-economic and biophysical
[64]	W. E. Thogmartin etal.	2014	Prairie Hardwood Transition of the United States	biophysical
[65]	C. J. Klein etal.	2014	Main islands of Fiji	biophysical
[66]	M. Duarte etal.	2014	Atacama Desert and Mediterranean Chile	socio-economic and biophysical
[67]	M. Mills etal.	2014	-	socio-economic and biophysical
[68]	H. X. Zhang etal.	2014	Xinjiang Urgur Autonomous Region (Province), northwest China	biophysical
[69]	R. D. Crego etal.	2014	Argentina	biophysical
[70]	W. JETZ etal.	2014	-	-
[71]	J. Junker etal.	2015	Liberia	socio-economic and biophysical
[72]	A. J. Mendoza-Fernández etal.	2015	South of the Iberian Peninsula (Andalusia)	biophysical
[73]	S. Naoe etal.	2015	Japan	biophysical
[74]	A. Lira-Noriega etal.	2015	Mexico	biophysical
[75]	M. J. Struebig etal.	2015	Borneo	biophysical
[76]	M. SCHRÖTER etal.	2015	-	-

Table 2: The main contribution for systematic conservation planning in reviewed papers

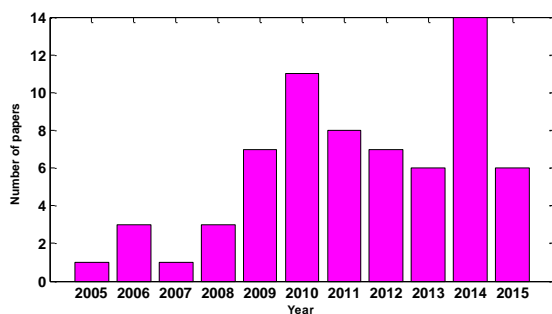| Number of Reference	Authors	Main Contribution
[10]	K. A. WILSON etal.	assessing the sensitivity of conservation planning outcomes to different uses of predicted species distribution data
[11]	W. J. ZIELINSKI etal.	Using empirically derived landscape suitability models for the spotted owl and the fisher to evaluate the overlap in habitat suitability for these predators
[12]	J. B. OETTING etal.	Introducing a systematic reserve design analysis with considering conservation needs for a variety of natural resources
[13]	CARLO RONDININI etal.	presenting a systematic reserve selection for 1654 African mammals and amphibians that uses habitat suitability models as estimates of the area occupied by each species
[14]	J. CARWARDINE etal.	comparing the irreplaceability of sites for protecting ecosystems using Marxan
		and C-Plan
[15]	S. D. Dlamini etal.	designing a landscape to conserve 44 landcover types, 53 species and 14 ecological processes
[16]	J. L. Pearce etal.	identifying priority areas for avian biodiversity with minimizing the area delineated and incorporating multiple criteria (species richness representation, spatial clustering) and biodiversity targets
[17]	B. Rayfield etal.	examining the relative merits of static and dynamic protected areas for the conservation of American marten habitat
[18]	S. Steiniger etal.	reviewing the use of GIS and GI tools in landscape ecology, with an emphasis on free and open source software (FOSS) projects
[19]	C. J. Klein etal.	developing two approaches to identify areas important for the conservation of biodiversity in terms of both wilderness quality and biodiversity representation
[20]	W. T. Langford etal.	proposing a conceptual structure for exploring the consequences of input uncertainty and oversimplified approximations to real-world processes for any conservation planning tool or strategy
[21]	M. A. Amis etal.	proposing a protocol for integrating the assessment of freshwater and terrestrial priorities in conservation planning
[22]	E. Lagabrielle etal.	mapping the spatial components of biodiversity processes and use these to design broad-scale conservation corridors
[23]	J. L. NEL etal.	presenting the freshwater component of the spatial assessment, aimed at identifying focus areas for expanding the national protected area system for the benefit of river biodiversity
[24]	R. LOURIVAL etal.	evaluating four conservation scenarios complied with the principles of systematic conservation planning and analyzed their representativeness, efficiency, and complementarily
[25]	P. J O'Farrell etal.	A brief reviewing of systematic conservation planning tools
[26]	S. J. Phillips etal.	Introducing a simple new index, "fraction-of-spare," for site prioritization,
[27]	S. B. Carvalho etal.	analyzing the effects of using different types of distribution data on the performance of reserve selection algorithms in scenarios
[28]	H. J. Edwards etal.	extending Marxan, to incorporate several important considerations related to biodiversity processes and management
[29]	E. Lagabrielle etal.	considering participatory modeling to integrate biodiversity conservation into land use planning and to facilitate the incorporation of ecological knowledge into public decision making for spatial planning
[30]	P. Visconti etal.	addressing both biodiversity processes and habitat loss in a scheduling framework by comparing four different prioritization strategies defined by MaxGain and MinLoss
[31]	V. M. Adams etal.	demonstrating that opportunity costs to single stakeholder groups can be inaccurate measures of true opportunity costs and can inadvertently shift conservation costs to affect groups of stakeholders disproportionately
[32]	C. N. Jenkins etal.	mapping the distribution of the remaining habitat for the 189 birds
[33]	M. Beger etal.	presenting a conceptual framework for systematic conservation prioritization that explicitly accounts for the connectivity between the terrestrial, marine, and freshwater realms
[34]	S. C. TROMBULAK	describing the efforts of the conservation organization to identify priority locations in the Northern Appalachian/Acadian ecoregion
[35]	P. R. HUBER etal.	comparing modeled conservation networks derived at regional and local scales from the same area in order to

		analyze the impact of scale effects on conservation planning		etal.	could affect the effectiveness of coarse-filter surrogates: thematic resolution, species' prevalence, and classification strength
[36]	S.R. Januchowski-Hartley etal.	deriving four abiotic and eight biologically informed classifications of stream reaches to serve as surrogates for biodiversity patterns	[56]	S. VALLECILLO etal.	formulating an approach to explicitly quantify the impact of fire on conservation areas, considering such disturbance as a driver of land-cover changes
[37]	E. Lagabrielle etal.	integrating ecological and socio-economic factors to identify the best spatial options for conserving and restoring biodiversity, inside and outside extant reserves, while minimizing future land-use conflicts	[57]	M. Yokogawa etal.	all five known wild populations and two artificially managed ex situ populations outside the species' native range of a critically endangered herb species in Japan, were studied, using 10 polymorphic microsatellite markers to assess the genetic consequences of habitat degradation on the wild populations and the establishment of ex situ populations
[38]	A. T. Knight etal.	interviewing land managers and mapping their willingness-to-sell their land using a psychometric analytical technique	[58]	Y. P. Lin etal.	proposing a two-stage conservation planning approach
[39]	B. N. Egoh etal.	identifying spatial priority areas for ecosystem services, testing the effect of different target levels of ecosystem services used to identify priority areas, and evaluating whether biodiversity priority areas can be aligned with those for ecosystem services	[59]	V. Hermoso etal.	developing a framework to identify a complementary set of priority areas and enhance the conservation opportunities of Natura 2000 for freshwater biodiversity
[40]	A.G. Rebelo etal.	considering the impacts of urbanization in a biodiversity hotspot	[60]	A. Mehri etal.	using three types of heuristic algorithms (simulated annealing, greedy, rarity) to prioritize areas for protection in Mazandaran Province of Iran
[41]	D. STRALBERG etal.	identifying priority shorebird and waterfowl areas at the ecoregional level	[61]	L. Zhang etal.	aiming to select a set of priority areas and to determine their priority order by quantifying human disturbances for each area in the Yangtze River Basin
[42]	B. A. NHANCALE etal.	using a dataset from southern Africa and measure the extent to which changing planning unit shape, size and baseline affects the results of conservation planning assessments	[62]	S. D. Langhans etal.	demonstrating a new approach to plan cost-effective river rehabilitation at large scales
[43]	S. R. JANUCHOWSKI-HARTLEY etal.	presenting a spatially explicit decision method that can be used to identify actions to manage invasive species while minimizing costs and the likelihood of reinvasion	[63]	D. Troupin etal.	using Marxan to select candidate sites for addition to an existing protected area system, based on three strategies
[44]	V. Hermoso etal.	evaluating the effect of grain size of species distribution data versus size of planning units on a set of performance measures describing efficiency, rate of commission errors, representativeness and a novel measure of overall conservation uncertainty	[64]	W. E. Thogmartin etal.	evaluating several management alternatives for conserving bird populations in the Prairie Hardwood Transition of the United States
[45]	R. Vimal etal.	developing a multi-criteria assessment of spatial variability of the vulnerability of three different biodiversity descriptors	[65]	C. J. Klein etal.	aiming to determine the benefit of different terrestrial reserve networks to the condition of coral reefs
[46]	R.A. Holland etal.	prioritizing amongst triggered catchments using a simple set of scenarios to examine the efficiency with which species can be represented and overlap with the existing PA network	[66]	M. Duarte etal.	assessing the implications for spatial conservation prioritization of the existence of two contrasting taxonomies
[47]	M. G. Zhang etal.	using species distribution modeling to improve conservation and land use planning	[67]	M. Mills etal.	discussing three potential contributions of social network analysis to systematic conservation planning
[48]	P. ORTEGA-BAES etal.	analyzing diversity patterns, to evaluate the effectiveness of the extant reserve network, to select the complementary areas for cactus conservation	[68]	H. X. Zhang etal.	investigating the patterns of woody species diversity and their relationship to environmental factors
[49]	U. S. ZEYDANLI etal.	Identifying 65 prime butterfly areas	[69]	R. D. Crego etal.	modeling the spatial distribution of meadows across arid and semi-arid Patagonia, Argentina, and investigating conservation status of those areas predicted to contain meadows
[50]	J. TRINDADE-FILHO etal.	assessing the effectiveness of 16 indicator groups in representing evolutionary and functional components of biodiversity	[70]	W. JETZ etal.	demonstrating how such a metric identifies species and regions of particular value for safeguarding evolutionary diversity
[51]	N. Apel etal.	demonstrating a novel approach for systematic conservation planning that incorporates dynamic ecological processes, biodiversity targets and management costs	[71]	J. Junker etal.	identifying priority areas for the protection of large mammals and biodiversity in Liberia under different conservation scenarios
[52]	J. Nackoney etal.	employing Marxan to develop a set of three scenarios of potential human and agricultural expansion for 2050 in Congo	[72]	A. J. Mendoza-Fernández etal.	Defining a new methodology combining the concepts of endemicity and threat in order to provide an objective and highly accurate selection of protected areas
[53]	P. Powers etal.	demonstrating how biological elements, intact forest landscapes; cost, and size considerations can be incorporated within spatial conservation planning tools	[73]	S. Naoe etal.	conducting complementarily analysis to achieve the target with regard to species distributions of 172 terrestrial birds in Japan
[54]	A. Gordon etal.	involving two agents sequentially purchasing land for the conservation of multiple species using three scenarios comprising either divergent or partially overlapping objectives between the agents	[74]	A. Lira-Noriega etal.	presenting the first priority assessment of freshwater ecosystems by in Mexico at the national scale
[55]	V. Hermoso	evaluating the role of three factors that	[75]	M. J. Struebig etal.	considering land use in priority areas for Borneo's mammals under combined land-cover and climate change projections
			[76]	M. SCHRÖTER etal.	reviewing and classifying methods to spatially delineate hotspots

III. CHRONOLOGICAL ANALYSIS

Totally, 67 papers were surveyed in this paper, covering the sufficient depth of works in the systematic conservation planning with Marxan in the landscape field for the time span of 2005 to 2015. Fig. 1 shows the percentage of the published papers about systematic conservation planning in landscape versus a one-year period from 2005 up to 2015. It can be surveyed that, in 2014, the maximum number of papers was published about this field (14% in each year) and, afterwards, 2010 was ranked second with 11%. It can be noted that the majority of papers considered the biophysical information for planning, demonstrating the important role of this information for decision-making.

Fig.1 Percentage of published papers about systematic conservation planning in seascape

IV. CONCLUSIONS

In this paper, almost 67 papers were surveyed about systematic conservation planning in landscape. Among these papers, the majority of papers considered bio physical information for planning and showed the importance of the information. Of course socio-economical information are key data for conservation planning and it is necessary that they are considered more for planning.

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